10

Nutrition

■ I. AIMS OF NUTRITIONAL SUPPORT

A. Preserve tissue mass and decrease usage of endogenous nutrient stores.

B. Decrease catabolism.

C. Maintain/improve organ function.
   1. Immune
   2. Renal
   3. Hepatic
   4. Muscle

D. Improve wound healing.

E. Decrease infection.

F. Maintain gut barrier (decrease translocation).

G. Decrease morbidity/mortality.
   1. Decrease ICU/hospital stay.
   2. Decrease hospital costs.

■ II. TIMING OF NUTRITIONAL SUPPORT

A. Optimal timing remains controversial.
   1. Some patients tolerate short periods of starvation by using endogenous stores to support body functions.
   2. Well-nourished patients (non-stressed) have actually survived without food for 6 weeks (ingesting only water).
   3. Hypermetabolic and hypercatabolic critically ill patients can probably only tolerate a few weeks of starvation before death.
   4. There appears to be no benefit of total starvation.

B. Accumulating data suggest that outcome can be improved with early and optimal nutritional support.

J. Varon, P. Acosta, *Handbook of Critical and Intensive Care Medicine*,
DOI 10.1007/978-0-387-92851-7_10,

1. Early nutritional support blunts the hypercatabolic/hypermetabolic response to injury.
2. In a growing number of studies, patients randomized to receive early vs. delayed feeding had decreased infection rates, fewer complications, and shorter length of stay in the hospital.
3. Animal studies report improved wound healing and improved hepatic function in several injury models with early feeding.

■ III. ROUTE OF NUTRITIONAL SUPPORT

A. Parenteral Nutrition
   1. Nutrients
      Amino acids, dextrose, soy-based lipids, vitamins, minerals and trace elements (see Table 10.1)
   2. Delivery: via peripheral or central vein
   3. Major complications
      a. Central line placement (pneumothorax, hemothorax, carotid artery perforation)
      b. Metabolic derangements (hyperglycemia, electrolyte disturbances)
      c. Immune suppression
      d. Increased infection rates (catheter-related sepsis, pneumonia, abscesses)
      e. Liver dysfunction (fatty infiltration, cholestasis, liver failure)
      f. Gut atrophy (diarrhea, bacterial translocation)
      g. Venous thrombosis
      h. Overfeeding
   4. Other problems include lack of some conditionally essential amino acids that are not stable in solution (i.e., glutamine, cysteine)

Table 10.1. Comparison of Nutrients in Enteral vs. Parenteral

Nutrient	*Enteral*	*Parenteral*
Nitrogen source	Intact proteins, peptides, or amino acids	Amino acids*
Carbohydrate	Simple sugars or complex carbohydrates (i.e., starch and fiber)	Simple sugar (dextrose)
Lipids	Long- and medium-chain triglycerides, or long-chain fatty acids (ω-3 or ω-6)	Soy-based lipids
Vitamins	Present	Can be added
Minerals and trace elements	Present	Can be added

* Lacks some conditionally essential amino acids (i.e., glutamine and cysteine).

5. Glucose/fat ratio
   a. Usually 60:40 to 40:60 (ratio of calories from each source)
   b. Large amounts of glucose (>60% of calories) can
      (1). Increase energy expenditure.
      (2). Increase CO_2 production and increase pulmonary workload (may delay ventilator weaning).
      (3). Produce liver steatosis.
      (4). Lead to immune compromise.

B. Enteral Nutrition
1. Nutrients (see Table 10.1)
   a. Nitrogen sources: amino acids, peptides, or intact proteins (e.g., casein, whey, soy, lactalbumin)
   b. Carbohydrates: simple sugars or complex carbohydrates (i.e., starch and fiber)
   c. Lipids: long- or medium-chain triglycerides, ω-3 or ω-6 long-chain fatty acids
   d. Vitamins
   e. Minerals and trace elements
2. Delivery
   a. Oral
   b. Gastric tube (i.e., nasogastric, gastric)
   c. Small-bowel feeding tube (i.e., nasoduodenal, gastroduodenal, jejunal)
3. Major Complications
   a. Aspiration (pneumonia, chemical pneumonitis, adult respiratory distress syndrome [ARDS])
   b. Metabolic derangements (e.g., electrolyte disturbances, hyperglycemia); these are less common than with parenteral nutrition
   c. Diarrhea
   d. Misplaced feeding tubes (e.g., pneumothorax, empyema, bowel perforation)
   e. Overfeeding

C. Enteral vs. Parenteral Nutrition
1. Enteral nutrition is required for optimal gut function (i.e., maintenance of gut barrier, gut-associated immune system, immunoglobulin A [Ig A] secretion, mucin layer)
2. Total parenteral nutrition (TPN) is associated with
   a. Immunosuppression (thought to be related to intravenous [IV] lipids, which are high in w-6 long-chain fatty acids)
   b. Increased infection rates (compared to enteral) in patients following trauma, burns, surgery, and cancer chemo/radiotherapy
   c. Higher mortality in patients receiving chemo/radiotherapy and after burn injury
3. TPN is not superior to enteral nutrition in patients with inflammatory bowel disease or pancreatitis.
4. TPN may be beneficial in patients with short-gut syndromes and some types of gastrointestinal (GI) fistulas.
5. Enteral nutrition is the preferred method of feeding in patients receiving chemo/radiotherapy, and following surgery, burns, trauma, sepsis, renal failure, liver failure, and respiratory failure.
6. Parenteral nutrition is indicated when enteral nutrition is not possible (i.e., inadequate small bowel function).

■ IV. GASTROINTESTINAL FUNCTION DURING CRITICAL ILLNESS

A. Oral nutrition remains the best form of nutritional support; however, in many critically ill patients, this is not possible.

B. Decreased motility of stomach and colon are common and typically last 5–7 days in critically ill patients (longer if the patient remains critically ill).
   1. Gastric paresis is best assessed and monitored by measuring gastric residuals.
   2. Gastric residuals of $\geq$150 mL are usually considered abnormal.
   3. Patients with gastric residuals $\geq$150 mL should be fed in the small bowel (postpyloric) to decrease risk of aspiration.

C. Motility and nutrient absorptive capability of small bowel is usually preserved (even after severe trauma, burns, or major surgery).

D. Bowel sounds are a poor index of small bowel motility.

■ V. NUTRIENT REQUIREMENTS (QUANTITY)

A. Energy
   1. Caloric Content of Major Nutrients
      a. Lipids provide 9 kcal/g.
      b. Carbohydrates provide 4 kcal/g.
      c. Proteins provide 4 kcal/g.
   2. Studies show that most critically ill patients expend 25–35 kcal/kg/d.
   3. One can estimate resting metabolic expenditure (RME) using the Harris-Benedict equation (see Table 10.2).
   4. One can also measure RME by indirect calorimetry (metabolic cart).
   5. Some recommend adjusting RME by multiplying by a correction factor (see Table 10.3); however, correction factors frequently overestimate energy needs.
   6. We prefer to initially administer 25 kcal/kg/d (see Table 10.4).
      a. $\approx$20% protein (percent refers to percentage of total daily calories)
      b. $\approx$30% lipids
      c. $\approx$50% carbohydrates
   7. Patients with organ failure/disease states may have increased or decreased needs and should be considered individually.

Table 10.2. Harris-Benedict Equations

Men	RME (kcal/d) = 66 + (13.7 × W) + (5 × H) – (6.8 × A)
Women	RME (kcal/d) = 665 + (9.6 × W) + (1.7 × H) – (4.7 × A)

Abbreviations: A, age in years; H, height in cm; RME, resting metabolic expenditure; W, weight in kg.

Table 10.3. Energy Expenditure Correction Factors

Starvation	0.7
Confined to bed	1.2
Out of bed	1.3
Fever	1 + 0.13/°C
Elective surgery	1.0–1.2
Multiple fractures	1.2–1.4
Sepsis	1.4–1.8
Burns	
<20% BSB	1–1.5
20–40% BSB	1.5–1.9
40–100% BSB	1.9–2.1

Abbreviation: BSB, body surface area burned.

Table 10.4. Macronutrient Nutritional Requirements

Nutrient	*% of total calories*	*Quantity of nutrients*	*Example for 70-kg patient*
Total calories		25 kcal/kg/d	1,750 kcal/d
Protein/amino acids	15–25	1.2–2.0 g/kg/d	95 g/d (380 kcal/d) (based on 1.35 g/kg/d)
Carbohydrates	30–65	50% of calories (avg pt)	220 g/d (880 kcal/d)
Fats	15–30	30% of calories (avg pt)	55 g/d (495 kcal/d)

8. Overfeeding (with either enteral or parenteral nutrients) is associated with more adverse side effects than slightly underfeeding during most critical illnesses.

B. Protein
1. Most critically ill patients need 1.2–2.0 g/kg/d.
2. Protein requirements increase in patients with severe trauma, burns, and with protein-losing enteropathies.

C. Water
1. Must be individualized, as needs vary greatly between patients (differences in insensible losses, GI losses, and urine losses).
2. Initially estimate: 1 mL water per kilocalorie of energy in adults.

D. Vitamins
1. Fat-soluble vitamins: A, D, E, K.
2. Water-soluble vitamins: ascorbic acid (C), thiamine (B_1), riboflavin (B_2), niacin, folate, pyridoxine (B_6), B_{12}, pantothenic acid, biotin.
3. Published recommended daily allowances (RDAs) are based on oral intake in healthy individuals.

Table 10.5. Micronutrient Nutritional Requirements

Micronutrient	*Enteral nutrition*	*Parenteral nutrition*	*Example for TPN for a 70-kg patient*
Minerals			
Sodium	60–140 mmol/d	60–120 mmol/d	80 mmol/d
Potassium	50–140 mmol/d	50–120 mmol/d	50 mmol/d
Magnesium	8–15 mmol/d	8–12 mmol/d	10 mmol/d
Phosphorous	25 mmol/d	14–16 mmol/d	15 mmol/d
Calcium	20 mmol/d	7–10 mmol/d	10 mmol/d
Trace elements			
Iron	10 mg/d	1–2 mg/d	none
Zinc	15 mg/d	2–5 mg/d	5 mg/d
Copper	2–3 mg/d	0.5–1.5 mg/d	1 mg/d
Chromium	50–200 μg/d	10–20 μg/d	10 μg/d
Selenium	50–200 μg/d	80–150 μg/d	100 μg/d
Iodine	150 μg/d	120 μg/d	120 μg/d
Manganese	2.5–5.0 mg/d	0.2–0.8 mg/d	0.5 mg/d
Vitamins*			
Vitamin A	RDA = 4,000–5,000 IU/d	ND	3,300 IU/d
Vitamin D	RDA = 200–400 IU/d	ND	200 IU/d
Vitamin E	RDA = 12–15 IU/d	ND	10 IU/d
Vitamin K	RDA = 60–80 μg/d	ND	10 mg/wk†
Thiamine	RDA = 1.1–1.4 mg/d	ND	3 mg/d
Riboflavin	RDA = 1.2–1.7 mg/d	ND	5 mg/d
Niacin	RDA = 13–19 mg/d	ND	40 mg/d
Pantothenic acid	4–7 mg/d‡	ND	15 mg/d
Pyridoxine	RDA = 1.6–2.0 mg/d	ND	4 mg/d
Folic acid	RDA = 0.4 mg/d	ND	0.4 mg/d
Vitamin B_{12}	RDA = 3 μg/d	ND	5 μg/d
Vitamin C	RDA = 40 mg/d	ND	100 mg/d
Biotin	RDA = 30–100 μg/d	ND	60 μg/d

Abbreviation: ND, not defined.

* Enteral requirements should always exceed parenteral requirements; most recommend supplying 1–3 times the RDA of each vitamin to patients with critical illness.

† None if anticoagulation used.

‡ RDA not established.

4. Vitamin needs for critically ill patients have not been determined.
5. See Table 10.5 for estimates of nutritional requirements of the vitamins.
6. Commercial enteral formulas generally supply the RDA of the vitamins (if patients receive their caloric needs).
7. An adult parenteral vitamin formulation was approved by the FDA in 1979 and is available for addition to TPN solutions; this should be added just before administration, since degradation can occur.

E. Minerals (Na, K, Ca, PO_4, Mg)
1. See Table 10.5 for estimates of daily nutritional requirements of the minerals.
2. Minerals are present in sufficient quantities in enteral products (special formulas limit electrolytes for renal failure).
3. Must be supplemented in TPN.

F. Trace Elements (iron, copper, iodine, zinc, selenium, chromium, cobalt, manganese)
1. Needs in critically ill patients have not been determined. (See Table 10.5 for estimates of requirements.)
2. Sufficient quantities are thought to be present in enteral products.
3. Must be supplemented in TPN (all except iron can be added to solution).
   a. Deficiency states have been reported in long-term TPN patients.
   b. Specifics are best managed by specially trained nutritional support teams.

■ VI. ROLE OF SPECIFIC NUTRIENTS (QUALITY)

A. Nitrogen Sources
1. Choices
   a. Amino acids
   b. Hydrolyzed protein (peptides)
   c. Intact proteins
2. Evidence suggests that peptides generated from the diet possess specific physiologic activities.
3. Nitrogen is best delivered as intact protein (if digestion and absorption intact) or hydrolyzed protein (impaired digestion).
4. Protein is absorbed primarily as peptides (60%) and amino acids (33%).
5. Essential amino acid formulas should ***not*** be used.
6. Some amino acids become essential during critical illness.
   a. These are called *conditionally essential amino acids.*
   b. Examples include glutamine, cysteine, arginine, and taurine.
7. Some amino acids appear to have specific roles.
   a. Glutamine is a fuel source for rapidly dividing cells, such as the GI tract and immune system (patients with bone marrow transplant, supplementation with glutamine was associated with lower rates of infection).
   b. Arginine is required for optimum wound healing and is important in immune function. (Target patients are critically ill adults and preterm infants.)
   c. Cysteine is needed for synthesis of glutathione.
   d. Branched-chain amino acids (BCAA) may improve mental status in patients with hepatic encephalopathy; it is primarily metabolized by peripheral muscle instead of the liver.
   e. Note that glutamine and cysteine are not stable (or present) in TPN solution.

B. Lipids
1. Linoleic Acid
   a. Essential fatty acid (need 7–12% of total calories supplied as linoleic acid)
   b. ω-6 Polyunsaturated, long-chain fatty acid (immunosuppressive)
   c. Precursor to membrane arachidonic acid
2. ω-3 Polyunsaturated Fatty Acids (PUFA)
   a. Fish oils and linolenic acid.

   b. Profound effects upon cell membrane fluidity and stability. Decrease production of dienoic prostaglandins (i.e., PGE_2), tumor necrosis factor, interleukin-1, and other proinflammatory cytokines.
   c. Supplementation of omega-3 fatty acids in patients with acute lung injury, improves oxygenation and shortens length of mechanical ventilation.
3. Medium-Chain Triglycerides
   a. Good energy source.
   b. Water-soluble.
   c. Enter circulation via GI tract.
4. Short-Chain Fatty Acids (SCFA)
   a. Examples: butyric and propionic acid
   b. Major fuel for the gut (especially the colon)
   c. Derived from metabolizable fiber
5. High-Fat Formulas
   a. If the patient is not overfed, these have little effect on CO_2 production (despite being marketed for decreasing the respiratory quotient [RQ]).
   b. Poor GI tolerance.

C. Carbohydrates
1. Starches and sugars: good for energy
2. Fiber
   a. Metabolizable fiber (i.e., pectin, guar) is converted to SCFA in the colon by bacteria.
   b. Bulk increases stool mass, softens stool, adds body to stool, and provides some stimulation of gut mass.

D. Dietary nucleic acids may be important for immune function.

■ VII. MONITORING RESPONSES TO NUTRITIONAL SUPPORT

A. Visceral Proteins
1. Prealbumin
   a. Half-life 2 days.
   b. Normal range is 10–40 mg/dL.
2. Transferrin
   a. Half-life 8–9 days.
   b. Normal range is 160–355 mg/dL.
3. Albumin
   a. Half-life 20 days.
   b. Normal range is 3.2–5.0 mg/dL.

B. Visceral protein levels are affected by nutritional intake as well as the disease state (especially presence of inflammation).

C. Increasing levels of visceral proteins suggest that nutritional support is adequate.

D. Nitrogen Balance
1. Determined from 12- to 24-h urine collections and measurements of total urinary nitrogen (more accurate than total urea nitrogen), compared to total nitrogen intake.

2. May be inaccurate
   a. In patients with renal failure
   b. If urine is not correctly collected by staff
   c. If the patient has increased nitrogen losses in stool or from wounds (i.e., burns)
3. N-balance = protein intake (g/d)/6.25 – {total urinary nitrogen (g/d) + 2}.
4. Negative nitrogen balance is not necessarily detrimental over the short term (i.e., 1–2 weeks).
5. Improvement in nitrogen balance suggests that nutritional support is adequate.
6. Be aware that nitrogen balance may improve as catabolism decreases despite inadequate nutritional support.

E. Caloric goals: caloric needs can be determined using 25 kcal/kg of ideal body weight as an estimate. Another option is indirect calorimetry:
1. Measures oxygen consumption and CO_2 production for 15–30 min, estimates energy expenditure, then extrapolates to 24 h.
2. Keep RQ <1. Values >1 suggest lipogenesis from excessive caloric intake; values $\approx$ 0.7 are found in starvation and reflect fat oxidation.

F. Other Nutritional Parameters Not Generally Useful in the Critically Ill
1. Weight
2. Skin-fold thickness
3. Delayed cutaneous hypersensitivity (DCH)
4. Lymphocyte counts

■ VIII. NUTRITION FOR SPECIFIC DISEASE PROCESSES

A. Acute Renal Failure
1. Use intact protein or peptide formula with moderate fat.
2. Do not restrict protein (it is required for healing and for other organ functions).
3. May limit fluid intake with double-strength formula (2 cal/mL).
4. Watch K, Mg, and PO_4 levels.

B. Hepatic Failure
1. Use intact protein or peptide formula.
2. Usually 1.0–1.2 g/kg/d of protein are needed to support repair and immune function.
3. BCAA may be of value if encephalopathy persists following use of intact protein or peptide diets.

C. Inflammatory Bowel Disease/Pancreatitis
1. Enteral nutrition is possible if a jejunal tube is placed (endoscopically or radiologically) distal to Treitz ligament.
2. Enteral nutrition should be attempted before initiating TPN.

D. Multiple Organ Failure
1. Nutritional support is usually of marginal value.
2. Nutritional support needs to be started before organ failure develops.

■ IX. NASODUODENAL FEEDING TUBE PLACEMENT

A. Use in patients who do not tolerate oral or gastric feeding.

B. Patients with abdominal surgery should have the tube placed during surgery under direct visualization.
   1. The anesthesiologist inserts the tube into the stomach.
   2. The surgeon locates the tube and directs it into the duodenum or jejunum.
   3. Eliminates need for confirmatory x-rays.
   4. Allows immediate feeding upon admission into intensive care unit (ICU).
   5. Feeding tubes may also be placed into the small bowel using a gastrostomy or jejunostomy.

C. Tubes placed into the stomach will rarely (5–15%) migrate spontaneously into the small bowel in critically ill patients (due to gastroparesis).

D. Bedside Method
   1. Place patient in left lateral decubitus position (if possible).
   2. Lubricate the nostril with generic lubricant or 2% viscous lidocaine.
   3. Insert an 8–10 French small-bore feeding tube (containing wire stylet) into the nostril, and gently advance it through the nasopharynx into the esophagus and then the stomach.
   4. If resistance is met or the patient coughs, becomes agitated, or decreases oxygen saturation, then
      a. Pull the tube back into the nasopharynx.
      b. Repeat step 3 and reinsert the tube into the stomach.
      c. Or, change the position of the patient's neck (slightly flex or extend) before reattempting insertion.
   5. Confirm position of the tube in the stomach.
      a. Auscultate over the abdomen.
      b. Aspirate gastric contents (pH $\approx$ 2–5, unless on H_2 blocker).
   6. Remove wire stylet, and place a 45-degree bend approximately 1 in. from the distal end of the wire.
   7. Gently reinsert the wire stylet (should not meet resistance).
   8. Slowly advance the tube while rotating it in a clockwise direction.
   9. Check the position every 10–15 cm.
      a. Auscultation will reveal higher pitched sounds when the tube is in the pylorus and proximal small bowel.
      b. Bile may be aspirated from the tube in the small bowel.
      c. Bile/small bowel secretions have pH $\approx$ 6–7.
      d. Abdominal x-ray.
         (1). Can confirm small bowel location.
         (2). May not be cost-effective.
         (3). Will avoid feeding into lung in rare case of misplaced feeding tube.

E. With this bedside method, we (faculty, residents, and medical students) successfully place >90% of attempted small bowel tubes into the duodenum or jejunum.

F. Aggressive surgical and bedside placement allows us to feed >97% of our critically ill patients enterally within 24–48 h of admission into the ICU.

G. If bedside placement is not possible, place the feeding tube into small intestine using
   1. Endoscopy
   2. Fluoroscopy

■ X. RECOMMENDATIONS FOR TPN USE

1. Use ***only*** when enteral nutrition is not possible (e.g., short-gut syndrome, chylothorax).
   a. Failure of the stomach to empty is not an indication for TPN but rather for a small bowel feeding tube.
   b. Most patients with diarrhea can be managed with enteral nutrition.
2. Initial TPN orders may be based on recommendations in Tables 10.4 and 10.5.
3. Overall TPN management is best performed by specially trained nutritional support teams.
4. For more specifics, the reader is referred to entire texts written about TPN.

■ XI. APPROACH TO ENTERAL FEEDING

A. Enteral nutritional support should be initiated within 12–48 h of admission to the ICU.

B. The oral route is preferred (but frequently not possible).

C. The gastric route is second choice and should be tried before placing a small bowel tube in most patients.

D. Patients at high risk for aspiration or known gastric paresis should be fed with a small bowel tube.

E. Feeding formulas should ***not*** be diluted.

F. Keep the head of the patient's bed elevated 30° to decrease the risk of aspiration.

G. Feeding should be started at 25–30 mL/h and increased by 25 mL/h every 1–4 h as tolerated by gastric residuals (<150 mL) until the caloric goal (25–30 kcal/kg/d) is achieved.

H. If the protein goal is not achieved, use a formula with a higher protein/calorie ratio or add protein to the formula.

I. Gastric residuals should be monitored every 4 h.

J. If the gastric residual is >150 mL, hold feeds for 2 h and then resume.

K. May increase feeds at slower rate (i.e., =10 mL/h every 6–12 h), but often this is not necessary.

L. The goal rate of infusion should be met by the third day of therapy (frequently earlier).

M. Monitor nutritional response by measuring visceral protein levels.

1. Prealbumin and transferrin levels should be measured on day 1 and every 3 days thereafter during initial therapy.
2. Increasing levels suggest that the patient is receiving adequate nutritional support.
3. Levels usually normalize in 1–2 weeks if the disease process is controlled and nutritional support is adequate.
4. If levels fail to increase,
   a. Consider underlying infection, inflammation, or other disease processes.
   b. Reevaluate the adequacy of nutritional support.
   c. Nitrogen balance and energy balance (i.e., indirect calorimetry) may be informative.
   d. Consult the nutritional support service.

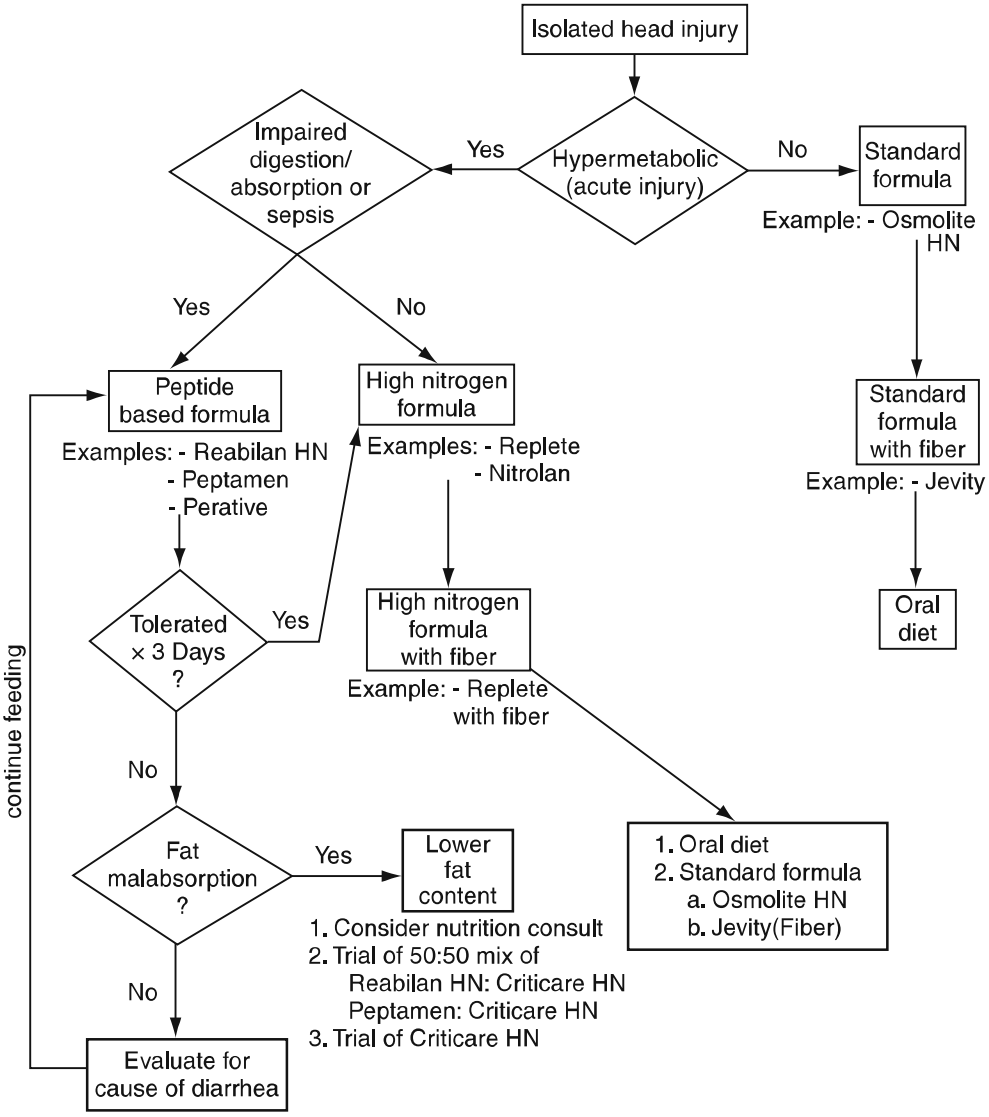

Figure 10.1. Flow diagram for nutritional support in patients with isolated head injury.

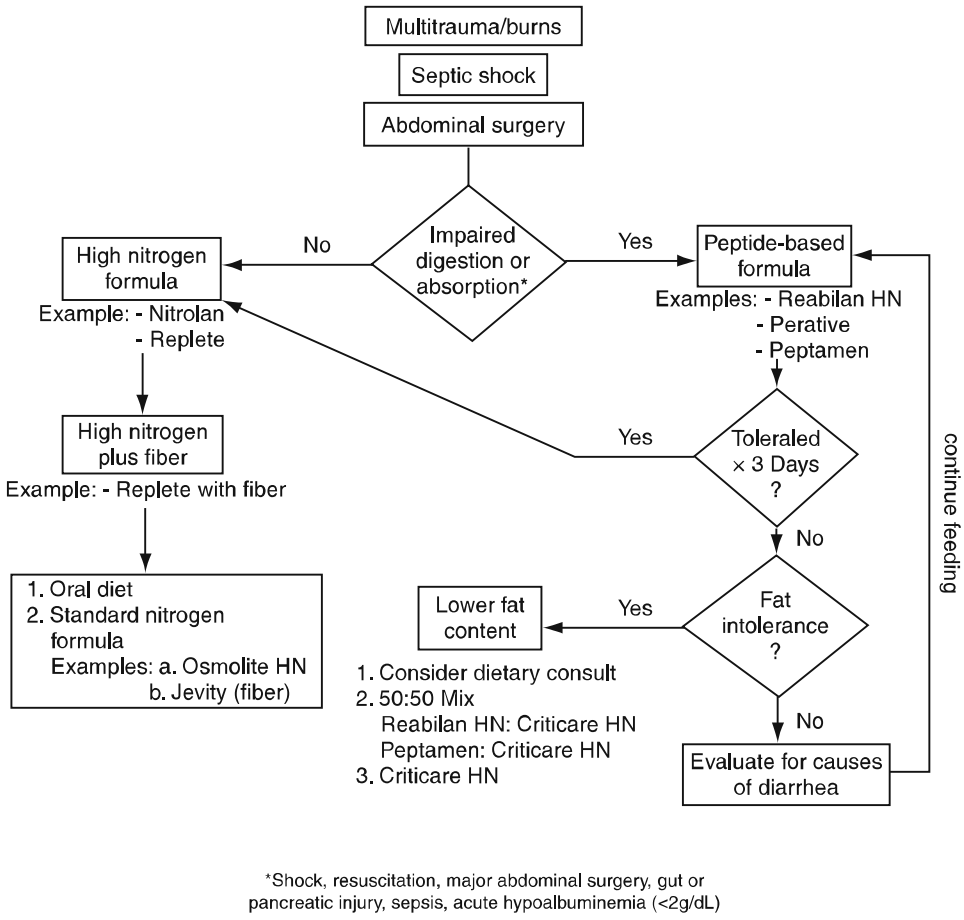

Figure 10.2. Flow diagram for nutritional support in patients with multiple trauma, burn injury, sepsis/septic shock, or abdominal surgery.

N. Several flow diagrams (for specific patient populations, using enteral products currently on our formulary) are given as examples (see Figures 10.1, 10.2, and 10.3).
   1. Isolated head injury (see Figure 10.1)
   2. Multitrauma, burn, sepsis, and abdominal surgery (see Figure 10.2)
   3. Severe malnutrition (see Figure 10.3)

O. If peptide-based diets are not available, intact protein diets should be used.

P. Formula Osmolality
   1. 300–600 mOsm/kg H_2O.
   2. Rarely causes intolerance/diarrhea.

Q. Diarrhea is unfortunately encountered in patients on enteral and parenteral nutrition.
   1. Generally defined as >300–500 mL stool output per day.
   2. Most common etiologies are medications and infections. See Table 10.6 for a partial list of etiologies and suggestions for preliminary workup.

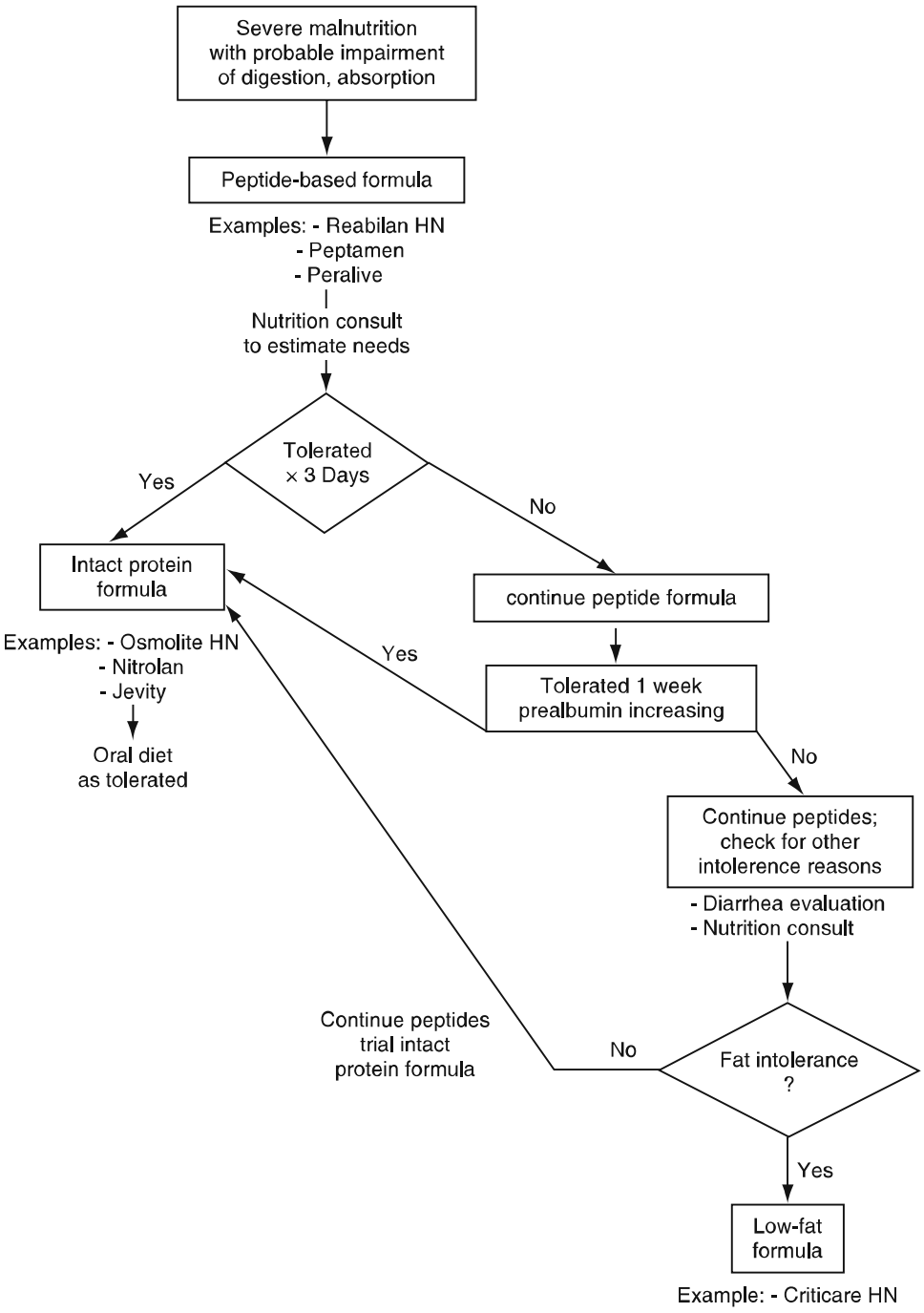

Figure 10.3. Flow diagram for nutritional support in patients with severe malnutrition.

3. Note that many elixir forms of medications contain sorbitol.
4. Once the specific etiologies of diarrhea have been evaluated, diarrhea may be treated with antimotility agents (i.e., narcotics). We prefer to add paregoric directly to the feeding formula (30–60 cc q4–6 h).

Table 10.6. Etiologies and Evaluation of Diarrhea

Causes	*Examples*	*Workup*
Drugs	Sorbitol, antacids, H_2 blockers, antibiotics, lactulose, laxatives, quinidine, theophylline	No specific workup; discontinue any of these medications that are not absolutely necessary
Infections	1. *Clostridium difficile*	1. Specific stool culture, *C. difficile* toxin assay, sigmoidoscopy/colonoscopy for evidence of pseudomembranes
	2. Infectious diarrhea (e.g., typhoid fever, shigellosis)	2. Fecal leukocytes, culture
	3. Other: bacterial overgrowth, parasites, systemic infection, HIV	3. As relevant (e.g., look for ova and parasites; rarely causes new diarrhea in critically ill)
Osmotic		Measure stool osmotic gap (SOG);* SOG >100 suggests osmotic diarrhea
Impaction	May be secondary to narcotics	Rectal exam
Other causes	Inflammatory bowel disease, pancreatic insufficiency, short gut syndrome	

* SOG = stool osmolality – 2(stool $Na^+ + K^+$).

■ XII. USEFUL FACTS AND FORMULAS

A. Nutritional Assessment. The *total daily energy* (TDE) requirements for a patient can be calculated using the following formula:

$$\text{TDE for men (kcal/d)} = (66.47 + 13.75\,\text{W} + 5.0\text{H} - 6.76\text{A}) \times (\text{Activity factor}) \times (\text{Injury factor})$$

$$\text{TDE for women (kcal/day)} = (655.10 + 9.56\,\text{W} + 1.85\text{H}4.68\text{A}) \times (\text{Activity factor}) \times (\text{Injury factor})$$

where W = weight (kg), H = height (cm), A = age (years); the activity factor is derived from Table 10.7.

The *injury factors* can be estimated based on the Table 10.8.

Table 10.7. Activity Factor

Confined to bed	1.2
Out of bed	1.3

Table 10.8. Injury Factors

Surgery	
Minor	1.0–1.1
Major	1.1–1.2
Infection	
Mild	1.0–1.2
Moderate	1.2–1.4
Severe	1.4–1.8
Trauma	
Skeletal	1.2–1.35
Head injury with steroid therapy	1.6
Blunt	1.15–1.35
Burns (body surface area)	
Up to 20%	1.0–1.5
20–40%	1.5–1.85
Over 40%	1.85–1.95

The *metabolic rate* (MR) can be calculated in patients with a pulmonary artery catheter as follows:

$$\begin{aligned}\text{MR(kcal/h)} = {} & \text{VO}_2\text{(mL/min)} \times 60\,\text{min/h} \\ & \times 1\text{L}/1000\text{mL} \times 4.83\,\text{kcal/L}\end{aligned}$$

where VO_2 (mL/min) = Cardiac output (L/min) × [arterial oxygen content (CaO_2, mL/L) – mixed venous oxygen content (CmO_2, mL/L)].

The *prognostic nutritional index* (PNI) allows for nutritional assessment of the critically ill patient and is calculated as follows:

$$\begin{aligned}\text{PNI}\,(\%\text{risk}) = {} & 158\% - 16.6\,(\text{alb}) - 0.78\,(\text{TSF}) \\ & -0.2(\text{tfn}) - 5.8(\text{DSH})\end{aligned}$$

where alb = serum albumin (g/dL); TSF = triceps skin fold (mm); tfn = serum transferrin (mg/dL); DSH = delayed skin hypersensitivity (1 = anergy, 2 = reactive).

The *probability of survival* (POS) based on the nutritional status of a critically ill patient can be calculated as follows:

$$\text{POS} = 0.91\,(\text{alb}) - 1.0\,(\text{DSH}) - 1.44\,(\text{SEP}) + 0.98\,(\text{DIA}) - 1.09$$

where alb = serum albumin (g/dL); DSH = delayed skin hypersensitivity (1 = anergy, 2 = reactive); SEP = sepsis (1 = no sepsis, 2 = sepsis); DIA = diagnosis of cancer (1 = no cancer, 2 = cancer).

Table 10.9. Index of Undernutrition

Assay	*Points*				
	0	*5*	*10*	*15*	*20*
Albumin (g/dL)	>3.5	3.1–3.5	2.6–3.0	2.0–2.5	<2.0
Fat area (%)	>70	56–70	46–55	30–45	<30
Muscle area (%)	>80	76–80	61–75	40–60	<40
Transferrin (g/L)	>2.0	1.76–2.0	1.41–1.75	1.0–1.4	<40
Weight lost (%)	0	0–10	11–14	15–20	>20

Another way to calculate the nutritional deficit is by utilizing the *index of undernutrition* (IOU), as shown in Table 10.9.
The calculation of *daily protein requirements* (PR) can be done utilizing the following formula:

$$\text{PR (g)} = \text{(Patient weight) in kg} \times \text{(PR for illness in g/kg)}$$

To determine the nonprotein caloric requirements (NCR):

$$\text{NCR} = \text{(Total required calories)} - \text{(Required protein calories)}$$

The *nitrogen balance* (NB) reflects the status of the net protein use:

$$\text{NB} = \text{(Dietary protein} \times 0.16) - \text{(UUN} + 2\,\text{g stool} + 2\,\text{g skin)}$$

where UUN = urine urea nitrogen.

In patients with renal failure, the increased blood urea pool and extrarenal urea losses must be accounted for:

$$\text{NB} = \text{Nitrogenin} - (\text{UUN} + 2\,\text{g stool} + 2\,\text{g skin} + \text{BUN change})$$

where BUN = serum urea nitrogen.

In addition to the above formulas, the *catabolic index* (CI) can be derived from the same variables:

$$\text{CI} = \text{UUN} - [(0.5 \times \text{Dietary protein} \times 0.16) + 3\,\text{g}]$$

No nutritional stress results in a CI ≥ 0, in moderate nutritional stress CI <5, and in severe nutritional stress CI >5.

Another index of the loss of lean tissue in malnourished patients is the *creatinine height index* (CHI) and can be calculated as follows:

$$\text{CHI} = \text{Measured creatinine/expected creatinine}$$

The *body mass index* (BMI) normalizes for height and allows comparisons among diverse populations:

$$\text{BMI} = \text{Body weight (kg)}/(\text{height})^2(\text{m})$$

B. **Fuel Composition**. The body uses different sources of fuel. Table 10.10 depicts some of them.

Table 10.10. Normal Fuel Composition of the Human Body

Fuel	*Amount (kg)*	*Calories (kcal)*
Circulating fuels		
Glucose	0.020	80
Free fatty acids (plasma)	0.0003	3
Triglycerides (plasma)	0.003	30
Total		113
Tissue		
Fat (adipose triglycerides)	15	141,000
Protein (muscle)	6	24,000
Glycogen (muscle)	0.150	600
Glycogen (liver)	0.075	300
Total		165,900

C. **Other Formulas**. The *body surface area* (BSA) of a patient can be calculated as follows:

$$\text{BSA}(\text{m}^2) = \frac{(\text{Weight in Kg})^{0.425} \times (\text{height in cm})^{0.725} \times 71.84}{10{,}000}$$

The *ideal body weight* (IBW) for height in males and females can be estimated based on Table 10.11.

Table 10.11. Ideal Body Weight in Males and Females

Height in cm	*Males (Weight in kg)*	*Females (Weight in kg)*
145	51.8	47.5
150	54.5	50.4
155	57.2	53.1
160	60.5	56.2
165	63.5	59.5
175	70.1	66.3
180	74.2	
185	78.1	

The *percentage of ideal body weight* (%IBW) is calculated as follows:

$$\%\text{IBW} = \frac{100 \times (\text{height in cm})}{\text{IBW}}$$